Electron quantum optics in quantum Hall edge channels

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The ballistic propagation of electronic waves along the quantum Hall edge channels of a two dimensional electron gas bears strong analogies with photon optics. Ballistic and one-dimensional propagation are ensured by the chiral quantum Hall edge states and electronic beam splitters can be implemented using quantum point contacts. These analogies have inspired a whole set of experiments, including the realization of electronic Mach-Zehnder [1] and Hanbury-Brown & Twiss [2] interferometers, providing an efficient tool to understand both the wave and corpuscular nature of electronic propagation in quantum conductors. However, some fundamental differences with photon optics remain as electrons are interacting fermions.

I will present optics-like experiments with electrons that push these analogies down to the single particle scale, where a single electronic excitation is emitted on-demand in the conductor.

In the first experiment [3], single elementary electronic excitations are emitted in one input only, and partitioned on the electronic beam-splitter. We show that the measurement of the output currents correlations in the HBT geometry provides a direct counting, at the single charge level, of the elementary excitations (electron/hole pairs) generated by the emitter at each cycle. We observe the antibunching of low energy excitations emitted by the source with thermal excitations of the Fermi sea already present in the input leads of the splitter, which suppresses their contribution to the partition noise. This effect can be used to probe the energy distribution of the emitted wave-packets which can be tuned by varying the emitter parameters.

The second experiment implements in a quantum conductor the electronic analog [4,5] of the experiment performed by Hong-Ou-Mandel [6] in quantum optics. Two single electronic excitations emitted on demand at each input collide on the splitter. When the arrival of one electron on the splitter is delayed with respect to the other, the random partitioning of classical particles is observed. On the contrary, we measure a reduction of the current fluctuations [7] at the outputs for perfect synchronization between the sources, showing the tendency of electrons to exit in two distinct output arms when they reach the splitter simultaneously. This Pauli dip, fermionic analog of the Hong-Ou-Mandel dip for photons, demonstrates our ability to produce on-demand coherent and indistinguishable electrons by independent emitters. However, we observe a reduction of the Pauli dip that could be caused by interaction induced decoherence.

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